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TECHNICAL REPORT ARCCB-TR-91023

CHARACTERIZATION OF M256 BORE EVACUATOR PERFORMANCE

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The performance of the M256 bore evacuator has been characterized by three ballistically different ammunition types. In addition, the First Round Combustion Phenomenon was explored for the first time.

TABLE OF CONTENTS

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The author would like to extend his sincere appreciation to Dr. Charles Andrade who first explained the concept of First Round Combustion Theory and to Jeffery Haas who participated in numerous thought-provoking discussions about bore evacuator functioning, as well as designing the pressure gage adapters used in live fire testing. Thanks also to Karen Bennett who helped with preparation of this and other technical reports, and Ralph Scutti and Rita Koerner who were Test Directors for these tests at the Combat Systems Test Activity, Aberdeen Proving Ground, MD. And a special thanks to Robert L. Rosenblum and Bernard J. Rowekamp, who in their own respective ways, have encouraged me to try harder in these endeavours.

STATEMENT OF THE PROBLEM

Since the beginning of M256 cannon development, detailed information on the performance of the bore evacuator for different ammunition types or under various levels of degraded function has not been developed.

To compensate for this shortfall of data, a test was conducted which tracked the function of the bore evacuator over its period of operation for three ammunition types in the normal configuration, as well as three possible modes of misassembly. Additionally, the phenomenon of First Round Combustion was explored for the first time.

BACKGROUND

The M256 bore evacuator is a pressure vessel which is charged with high pressure gas during firing of the cannon. As pressure inside the bore decreases, accumulated gas inside the bore evacuator is exhausted through the tube's bore evacuator holes and flows toward the muzzle end. When the metal stub case is ejected from the tube's chamber end, as the breech opens, a sympathetic flow begins which draws smoke through the bore of the cannon tube and exhausts it out the muzzle end. The proper function of the bore evacuator is directly related to its rate of discharge, its rate of leakage (if any), and the peak pressure inside the evacuator.

The First Round Combustion Theory is a potential explanation for the higher peak pressures experienced on the first round of firing or the first round fired after bore evacuator assembly. This suggests that the high temperature fuel-rich exhaust gases, which exist immediately after propellant ignition, combine explosively with the oxygen-rich air present inside the bore evacuator chamber. On subsequent rounds, only oxygen-depleted exhaust gases remain in the evacuator; the author can confirm this portion of the theory from personal observation of exhaust gases trapped inside the bore evacuator as much as ten minutes after the last round fired. The absence of oxygen-bearing air inside the bore evacuator accounts for the lower pressures (relative to the first round) observed on all subsequent rounds. The higher pressure excursion will not recur until oxygen is reintroduced into the evacuator by a long period of inactivity or by disassembly and subsequent reassembly.

APPROACH TO THE PROBLEM

The following factors can potentially affect proper bore evacuation

- obstruction of the tube bore evacuator holes (inhibiting charging),
- bore evacuator damage permitting leakage;
- missing O-rings permitting leakage;
- loose bore evacuator nut permitting leakage, and
- removal of the stub case at the chamber end after complete bore evacuator discharge.

Of these factors, the three misassembly possibilities were incorporated into the live fire test plan to observe their effect on bore evacuator operation. These configurations included missing O-rings with a properly tightened bore evacuator nut, O-rings present with a loose (3.2-mm gap) bore evacuator nut, and missing O-rings with a loose bore evacuator nut.

Since pressure inside the tube bore charges the bore evacuator and induces its peak pressure, three different round types were selected to observe any differences in bore evacuator operational parameters. The kinetic energy (KE) tactical round (M829) was used only to obtain normal bore evacuator configuration pressure data for that round, while the KE trainer round (M865) and high explosive antitank (HEAT) trainer round (M831) were used to obtain data for all configurations. The HEAT trainer round (M831) and HEAT tactical round

(M830) generate the same bore pressures and muzzle velocities and are regarded as ballistically identical.

The phenomenon of First Round Combustion was simulated by introducing a phase of testing where the bore evacuator was disassembled between rounds to permit venting of the combusted gases inside the evacuator and to allow fresh oxygen-bearing air into the evacuator before it was reassembled to the cannon tube.

This testing was accomplished simultaneously with another test program and represented a cost effective use of government test assets, personnel, and, of course, funding.

The following test procedure and firing sequence are extracted from Reference 1.

Test Procedure

- Wind velocity and direction, temperature, precipitation, and relative humidity shall be similar for each firing event.
- All rounds shall be certified as coming from the same ammunition lot.
- An event timer shall be used during testing to create a bore evacuator charge/discharge curve for each firing event.
- Induced bore evacuator leakage shall be accomplished by removing O-rings or by simple hand-tightening of the bore evacuator nut, whichever is specified by the test phase.
- For each round record the following data:
  1. shot initiation time,
  2. bore evacuator pressure versus time, and
  3. round type.
- The same cannon tube shall be used for all test phases.

Test Firing Sequence

Step	Condition	Quantity		
		M865	M831	M829
A	Normal with MS9021-371 O-rings	10	10	10
B	Misassembled, missing O-rings	10	10	--
C	Misassembled, BE Nut gap with O-rings	10	10	--
D	Misassembled, BE Nut gap, missing O-rings	10	10	--
E	Normal with introduction of fresh oxygenated-air between rounds	10	10	--
F*	Purge with nitrogen between rounds	10	10	--

*This phase was not part of the original test plan but was introduced during testing at Aberdeen Proving Ground, MD.

RESULTS

As expected, the bore evacuator configuration with the best performance was the evacuator configured with O-rings and a properly tightened bore evacuator nut. This configuration typically delivered discharge durations slightly better than 1500 milliseconds. When O-rings were removed, peak pressure remained the same, however, the evacuator discharge durations dropped to slightly less than 1000 milliseconds. The degradation continued when the bore evacuator nut was left loose resulting in duration times on the order of 500 milliseconds.

Peak pressures were fairly consistent for each round type with the KE tactical round (M829) delivering the highest peak pressure of about 88 lbs psi (under normal operating conditions), followed by KE trainer (M865) at 70 lbs psi and HEAT trainer at about 65 lbs psi.

Peak pressure increased substantially when the bore evacuator was disassembled between rounds to permit purging of the combusted gases and replacement with oxygen-bearing air.

During the firing of the M829 rounds it was noted that pressures gradually reduced during subsequent firings. One possible explanation for this is that these rounds were fired during dispersion testing which necessitated an extended idle time between rounds for checking targets and performing muzzle bore sighting of the cannon. The extended idle times may have allowed the slow migration of oxygen-bearing air into the bore evacuator chamber producing higher than nominal pressures on subsequent rounds until the test firing pace increased.

Additional evidence to confirm the First Round Combustion Theory was obtained during the nitrogen-purging sequence. This procedure removed combusted gases and introduced inert nitrogen into the evacuator chamber prior to firing. Pressure values for this series of rounds were comparable to those in normally configured bore evacuators without the presence of First Round Combustion.

Results and figures associated with the testing are contained in the Appendix.

CONCLUSIONS

The absence of O-rings or the improper tightening of the bore evacuator nut can have a severe impact on bore evacuator function. Bore evacuator integrity is important for the efficient removal of toxic combusted gases from the chamber of the cannon before they enter the fighting compartment. In order for this to occur, the bore evacuator pressure at the time of breech opening must be as high as possible to develop sufficient flow velocity and duration to start and maintain the flow of exhaust gases from the breech end to the muzzle end of the cannon tube. When the bore evacuator is misassembled, pressure inside the evacuator chamber decays at an accelerated rate which produces lower induced exhaust flow in the bore of the cannon tube, if it develops at all.

The different pressure levels in the bore evacuator related to ammunition type can be directly attributed to the different pressures present in the tube bore at the time of evacuator charge-up. It follows that the KE tactical round produces the highest bore pressure and therefore the highest bore evacuator pressure of the different ammunition types tested. Conversely, the HEAT trainer round produces the lowest bore pressure and the lowest bore evacuator pressure. As ammunition chamber pressure increases, the bore evacuator pressure increases. When this is coupled with a properly assembled bore evacuator, pressure in the evacuator chamber at the time of breech opening is also higher. This brings about higher induced velocities at the breech end of the cannon tube

First Round Combustion may provide an increase in bore evacuator efficiency since evacuator pressure remains slightly elevated at the time of breech opening compared to an unaugmented evacuator. This higher pressure level could potentially produce a qualitative improvement in induced flow at the breech end of the cannon. Testing of this concept will be pursued.

REFERENCE

1. Letter from SMCAR-CCB-DP to STECS-CC-PC, Subject: Test Plans, Gun Tube and Bore Evacuator, 120-mm Gun M256, Benet Laboratories, Watervliet, NY, dated 8 March 1990.

APPENDIX

Bore Evacuator Pressure Time Curve Data

TABLE A-I. BORE EVACUATOR TESTING

4 April 1990 M865

Round No.	Pressure	Discharge Time	Condition
31	65.0	1.70	a)
32	66.0	1.70	a)
33	68.0	1.76	a)
34	69.0	1.77	a)
35	69.0	1.76	a)
36	71.0	1.76	a)
37	72.0	1.76	a)
38	74.0	1.73	a)
39	75 0	1.75	a)
40	75.0	1.74	a)

Average Pressure 70.4 lbs psi
Average Time· 1.74 sec
Pressure Standard Deviation· 3.4 lbs psi
Time Standard Deviation 0.02 sec

Condition Key
a) Normal

TABLE A-II. BORE EVACUATOR TESTING

22 May 1990 M865

Round No.	Pressure	Discharge Time	Condition
21	LOST	LOST	b), *)
22	67.0	0.85	b)
23	65.0	0.85	b)
24	65.0	0.86	b)
25	66.0	0.85	b)
26	64.0	0.87	b)
27	64.0	0.87	b)
28	64.0	0.90	b)
29	65.0	0.88	b)
30	64.0	0.92	b)

Average Pressure: 64.9 lbs psi
Average Time: 0.87 sec
Pressure Standard Deviation. 0.99 lbs psi
Time Standard Deviation: 0.02 sec

Condition Key.
b) Missing O-rings
*) Data Discarded

TABLE A-III. BORE EVACUATOR TESTING

4 April 1990 M865

Round No.	Pressure	Discharge Time	Condition
51	67.0	1.22	c)
52	68.0	1.08	c)
53	70.0	1.10	c)
54	71.0	1.10	c)
55	73.0	1.00	c)
56	74.0	1.10	c)
58	77.0	1.10	c)
59	77.0	1.10	c)
60	77.0	1.00	c)

Average Pressure: 72.9 lbs psi
Average Time: 1.08 sec
Pressure Standard Deviation: 3.60 lbs psi
Time Standard Deviation: 0.06 sec

Condition Key
c) Loose BE Nut

TABLE A-IV. BORE EVACUATOR TESTING

16 April 1990 M865

Round No.	Pressure	Discharge Time	Condition
91	134.0	0.48	e), *)
92	73.0	0.50	d)
93	72.0	0.50	d)
94	71.0	0.47	d)
95	LOST	LOST	d), *)
96	71.0	0.47	d)
97	71.0	0.47	d)
98	73.0	0.50	d)
100	71.0	0.47	d)

Average Pressure: 71.9 lbs psi
Average Time 0.48 sec
Pressure Standard Deviation: 0.90 lbs psi
Time Standard Deviation: 0.01 sec

Condition Key:
d) Loose BE Nut and Missing O-rings
e) First Round Combustion
*) Data Discarded

TABLE A-V. BORE EVACUATOR TESTING

16 April 1990 M865

Round No.	Pressure	Discharge Time	Condition
101	169.0	1.61	e)
102	165.0	1.61	e)
103	164.0	1.61	e)
104	160.0	1.61	e)
105	165.0	1.61	e)
106	163.0	1.61	e)
107	162.0	1.61	e)
108	163.0	1.61	e)
109	163.0	1.61	e)
110	161.0	1.61	e)

Average Pressure· 162.9 lbs psi
Average Time. 1 61 sec
Pressure Standard Deviation· 1.59 lbs psi
Time Standard Deviation 0.00 sec

Condition Key
e) First Round Combustion

TABLE A-VI. BORE EVACUATOR TESTING

5 April 1990 M831

Round No.	Pressure	Discharge Time	Condition
21	192.0	1.40	e), *)
22	71.0	1.54	a)
23	70.0	1.62	a)
24	68.0	1.53	a)
25	67.0	1.50	a)
26	64.0	1.58	a)
27	62.0	1.59	a)
28	62.0	1.60	a)
29	60.0	1.72	a)
30	60.0	1.70	a)

Average Pressure: 64.9 lbs psi
Average Time 1.60 sec
Pressure Standard Deviation. 3.9 lbs psi
Time Standard Deviation 0.07 sec

Condition Key:
a) Normal
e) First Round Combustion
*) Data Discarded

TABLE A-VII. BORE EVACUATOR TESTING

19 April 1990 M831

Round No.	Pressure	Discharge Time	Condition
31	59.0	0.86	b)
32	59.0	0.90	b)
33	59.0	0.90	b)
34	62.0	0.90	b)
35	63.0	0.86	b)
36	59.0	0.89	b)
37	61.0	0.86	b)
38	59.0	0.86	b)
39	60.0	0.86	b)
40	59.0	0.85	b)

Average Pressure. 60.0 lbs psi
Average Time: 0.87 sec
Pressure Standard Deviation. 1.41 lbs psi
Time Standard Deviation 0.02 sec

Condition Key
b) Missing O-rings

TABLE A-VIII. BORE EVACUATOR TESTING

5 April 1990 M831

Round No.	Pressure	Discharge Time	Condition
41	63.0	1.52	c), *)
42	65.0	1.55	c), *)
43	65.0	1.50	c), *)
44	64.0	1.57	c), *)
45	64.0	1.58	c), *)
46	62.0	1.65	c), *)
47	62.0	1.64	c), *)
48	62.0	1.70	c), *)
49	61.0	1.60	c), *)
50	61.0	1.78	c), *)

Average Pressure: 62.9 lbs psi
Average Time: 1.61 sec
Pressure Standard Deviation 1.45 lbs psi
Time Standard Deviation: 0.08 sec

Condition Key:
c) Loose BE Nut
*) Data Discarded

TABLE A-IX. BORE EVACUATOR TESTING

24 May 1990 M831

Round No.	Pressure	Discharge Time	Condition
111	65.0	0.54	d)
112	64.0	0.58	d)
113	63.0	0.58	d)
115	63.0	0.60	d)
116	63.0	0.60	d)
117	61.0	0.52	d)
119	62.0	0.52	d)
120	63.0	0.53	d)

Average Pressure: 63.0 lbs psi
Average Time 0.56 sec
Pressure Standard Deviation: 1.10 lbs psi
Time Standard Deviation: 0.03 sec

Condition Key.
d) Loose BE Nut and Missing O-rings

TABLE A-X. BORE EVACUATOR TESTING

24 May 1990 M831

Round No.	Pressure	Discharge Time	Condition
91	63.0	0.93	e), *)
92	149.0	0.83	e), *)
93	149.0	0.78	e), *)
94	147.0	0.78	e), *)
95	146.0	0.78	e), *)
96	150.0	1.49	e)
97	147.0	1.30	e)
98	LOST	LOST	e), *)
99	142.0	1 49	e)
100	142.0	1.39	e)

Average Pressure: 145.3 lbs psi
Average Time: 1.42 sec
Pressure Standard Deviation 3.42 lbs psi
Time Standard Deviation. 0.08 sec

Condition Key:
e) First Round Combustion
*) Data Discarded

TABLE A-XI. BORE EVACUATOR TESTING

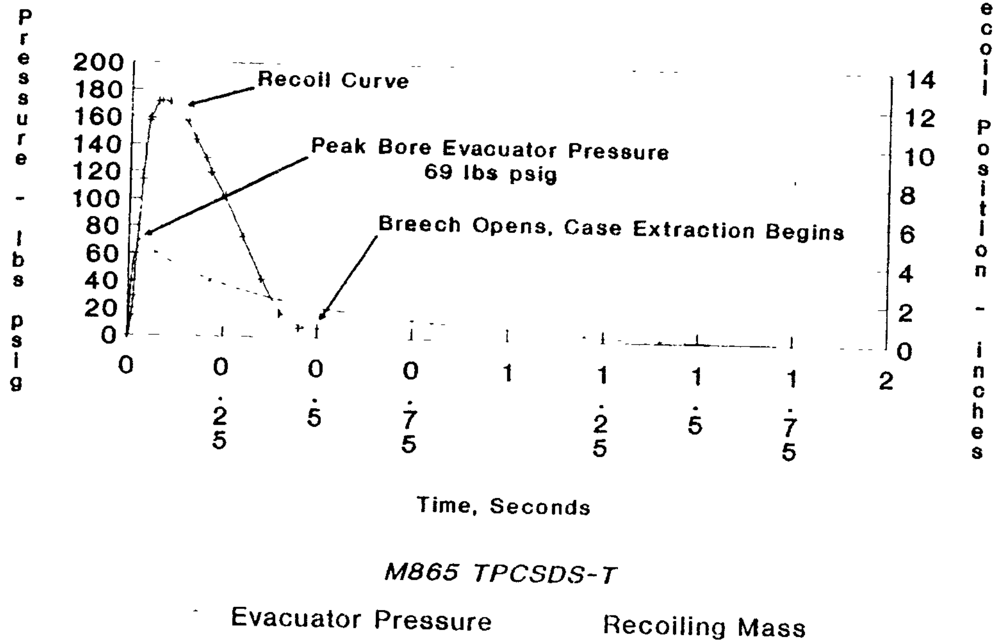
19 April 1990 M829

Round No.	Pressure	Discharge Time	Condition
D3-1	200.0	0.99	e), *)
D3-2	142.0	1.35	e), *)
D3-3	118.0	1.24	e), *)
D3-4	107.0	1.35	e), *)
D3-5	94.0	1.39	a)
D3-7	88.0	1.51	a)
D3-8	LOST	LOST	a), *)
D3-9	84.0	1.55	a)
D3-10	84.0	1.55	a)

Average Pressure: 87.8 lbs psi
Average Time: 1.49 sec
Pressure Standard Deviation: 3.71 lbs psi
Time Standard Deviation: 0.06 sec

Condition Key.
a) Normal
e) First Round Combustion
*) Data Discarded

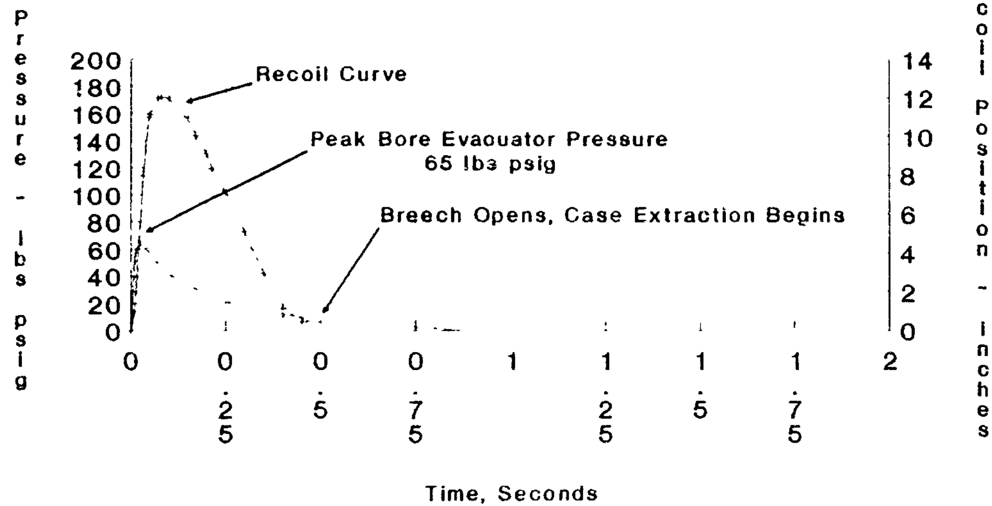
Cannon, 120mm Gun: M256
Evacuator Pressure and Recoil Position
vs. Time



Round No. 35, Normal

Figure A-1

Cannon, 120mm Gun: M256
Evacuator Pressure and Recoil Position vs. Time



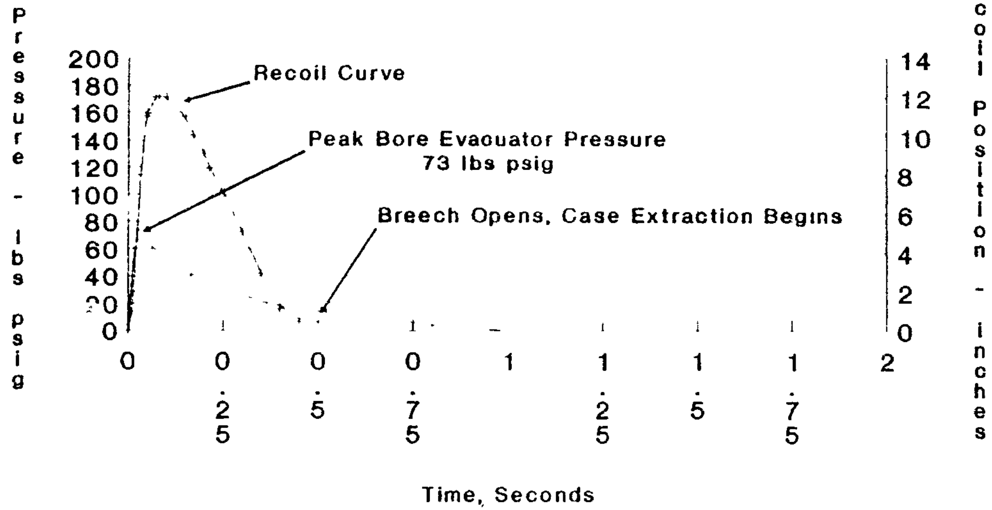
M865 TPCSDS-T

Evacuator Pressure Recoiling Mass

Round No. 24, Configuration B

Figure A-2

Cannon, 120mm Gun: M256
Evacuator Pressure and Recoil Position vs. Time



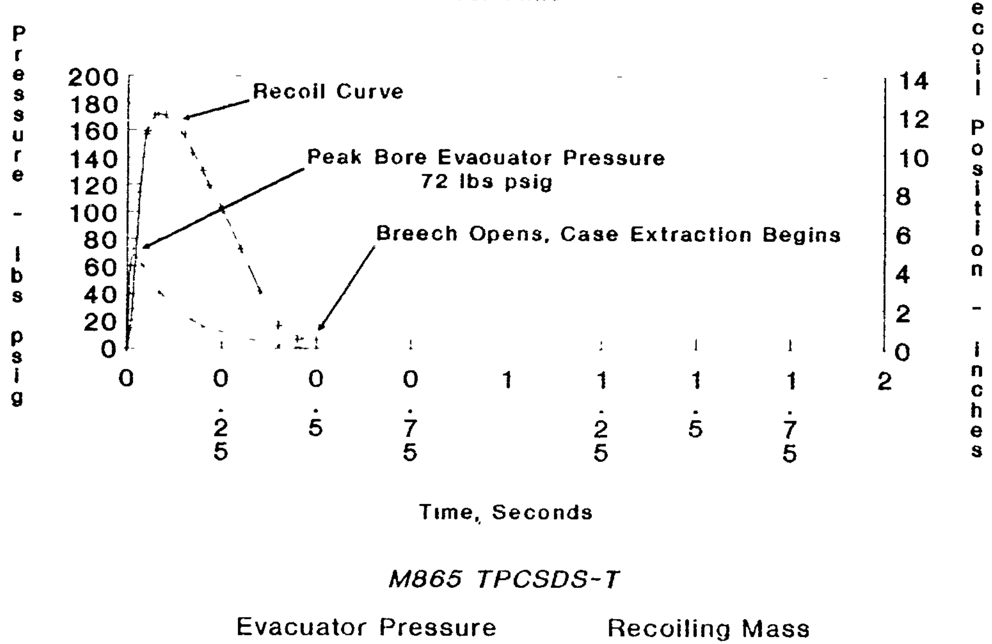
M865 TPCSDS-T

Evacuator Pressure Recoiling Mass

Round No. 55, Configuration C

Figure A-3

Cannon, 120mm Gun: M256
Evacuator Pressure and Recoil Position
vs. Time

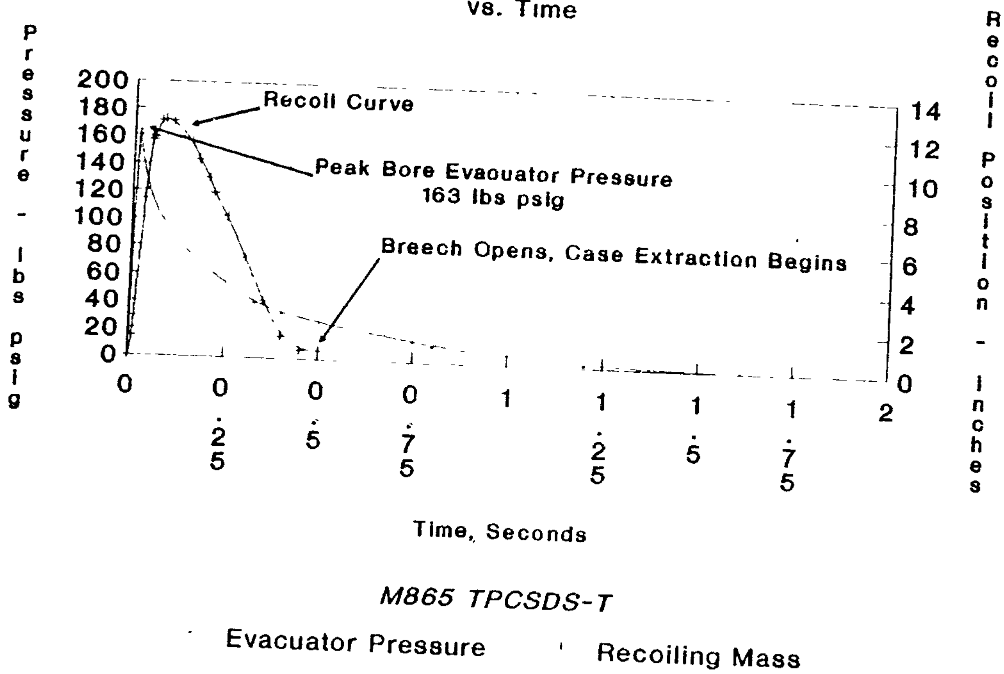


Round No. 93, Configuration D

Figure A-4

Cannon, 120mm Gun: M256

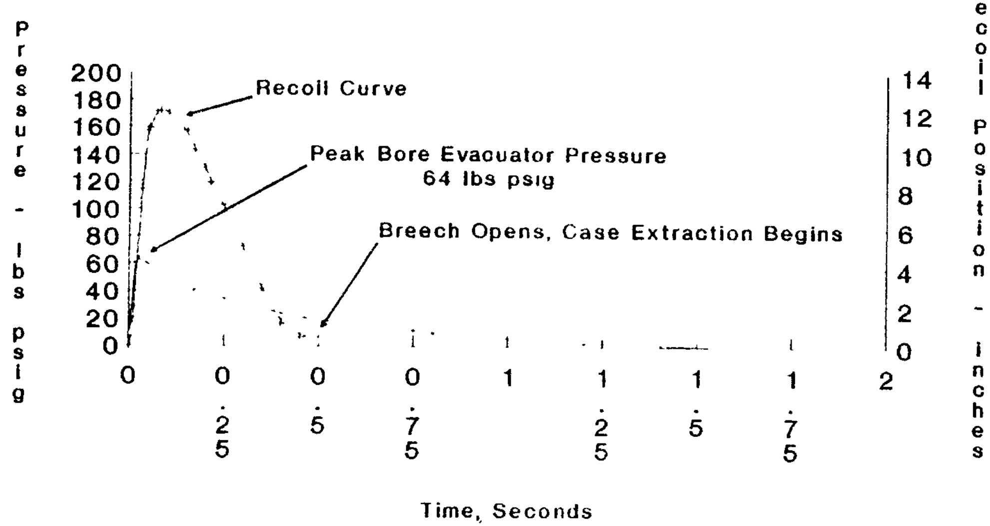
Evacuator Pressure and Recoil Position vs. Time



Round No. 106, First Round Combustion

Figure A-5

Cannon, 120mm Gun: M256
Evacuator Pressure and Recoil Position
vs. Time



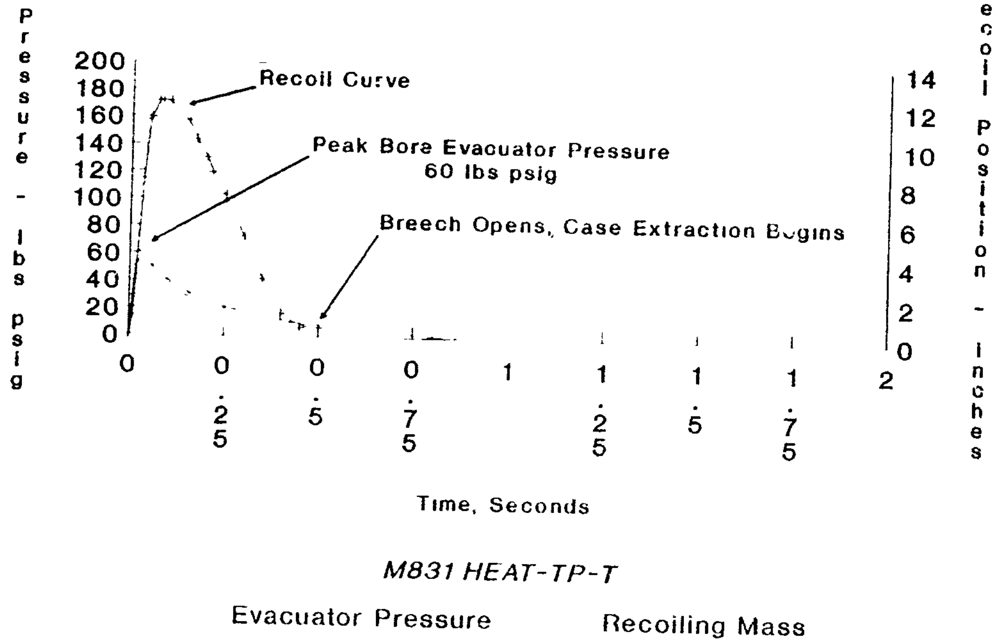
M831 HEAT-TP-T

Evacuator Pressure   Recoiling Mass

Round No. 26, Normal

Figure A-6

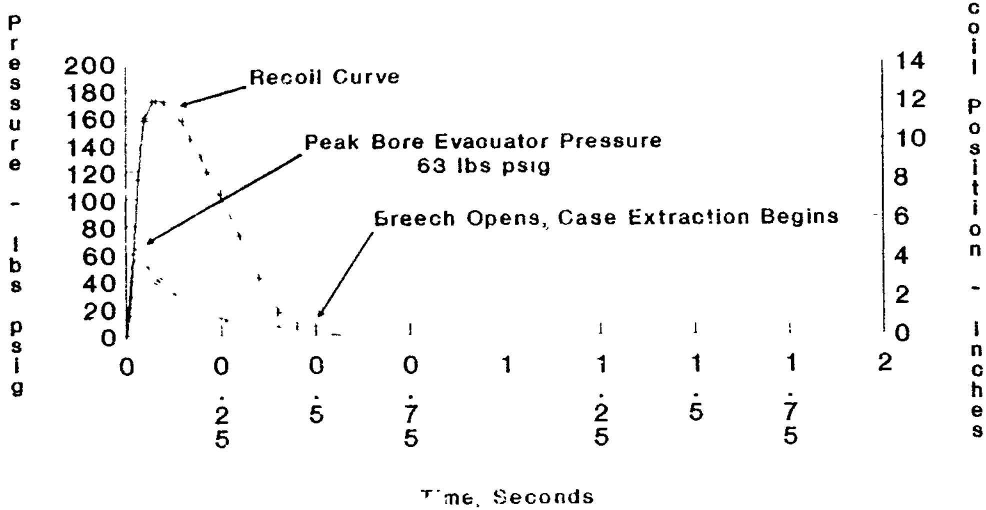
Cannon, 120mm Gun: M256
Evacuator Pressure and Recoil Position vs. Time



Round No. 39, Configuration B

Figure A-7

Cannon, 120mm Gun: M256
Evacuator Pressure and Recoil Position
vs. Time



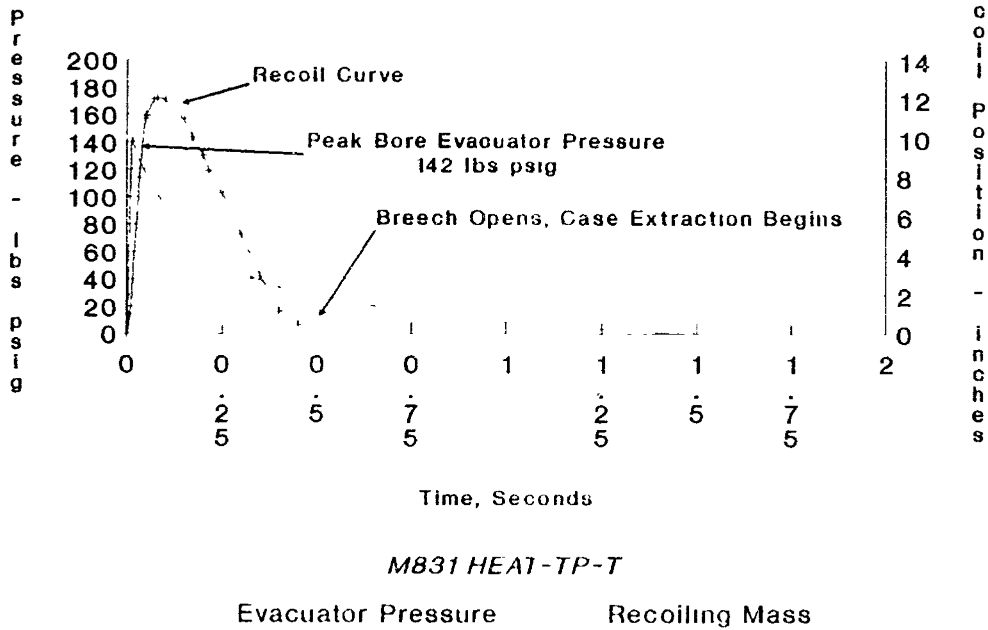
M831 HEAT-TP-T

Evacuator Pressure Recoiling Mass

Round No. 113, Configuration D

Figure A-8

Cannon, 120mm Gun: M256
Evacuator Pressure and Recoil Position
vs. Time

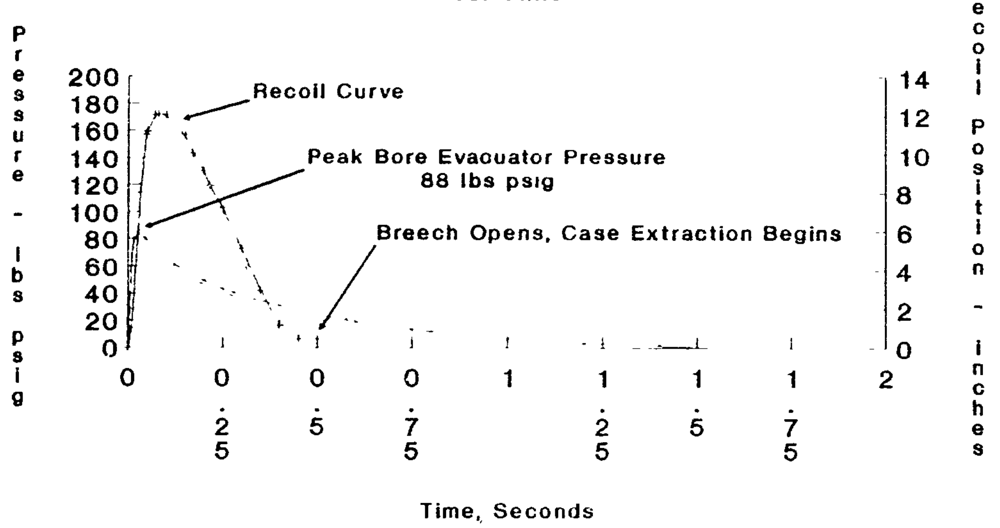


Round No. 99, First Round Combustion

Figure A-9

Cannon, 120mm Gun: M256

Evacuator Pressure and Recoil Position vs. Time



M829 APFSDS-T

Evacuator Pressure   Recoiling Mass

Round No. D3-7, Normal

Figure A-10

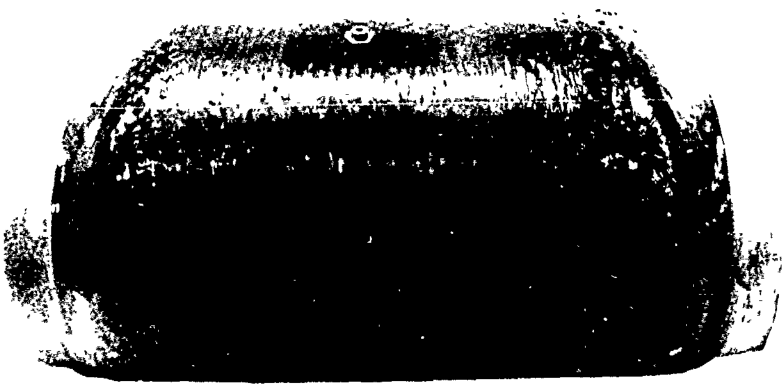


Figure A-11. M256 bore evacuator with pressure tap adaptor used in testing.

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